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CONTENTS

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EFFECT OF DATE AND METHOD OF KILL ON YIELD, SPECIFIC GRAVITY AND OTHER QUALITY FACTORS OF MAINE POTATOES

G. L. Terman, C. E. Cunningham, and Michael Goven[1,2]

Under conditions of heavy fertilization and effective disease and insect control, potato vines usually remain alive in Maine until killed by frost or other means. Since yields tend to increase as long as the vines remain alive, growers are reluctant to stop growth until as late in the season as possible. Potatoes grown for early market or killed early to reduce disease spread are exceptions. Most of the Maine crop, however, is harvested before the tuber skins are set properly, and excessive skinning frequently results.

The effects of time, method and rate of kill on yield, appearance, and total solids content of potatoes have not been adequately determined. This paper presents results of an attempt to combine these effects on yield, specific gravity, skinning, mechanical injury and storage characteristics of four potato varieties. No published report of the results of combining the above effects in a single study has been found.

Methods and Materials

Most of the results reported below were obtained from a field plot experiment conducted at Presque Isle, Maine in 1951. Four varieties of potatoes — Chippewa, Green Mountain, Katahdin, and Kennebec — were grown in variety blocks of 2-row plots 20 feet long. The vines of 2 replications of each variety were killed by three methods on three dates 10 days apart — August 14, August 24, and September 3. The three methods of kill were: (a) rapid destruction by cutting, (b) rapid chemical kill with a dinitro vine killer, and (c) a slower chemical kill with an arsenical vine killer. A second application of the sprays was made 5 days after the first application. Dinitro spray was also used on the vine stubs left from cutting to prevent new growth. The dinitro and arsenical sprays resulted in the death of leaves in 2-3 days and 3-5 days, respectively, with the stems remaining green a few days longer. Kill of stems was fairly complete 10 days after the first treatment, or at the time of the first harvest.

On other plots the vines were not killed, tubers being harvested from the green, naturally maturing vines. Tubers from all plots were harvested by hand and weighed at approximately 10 and 20-day intervals after each date of kill.

The specific gravity was determined by weighing duplicate 20-tuber samples of uniform size in air and water. These samples were saved and stored in a bin having a constant temperature of 40° F. and a relative humidity of 75 to 80 per cent. Weight and specific gravity

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determinations were made December 11-20 and March 21-31. Cores of 10 tubers of each sample were then French fried and observations on color and mealiness recorded.

Samples of tubers were subjected to a standard treatment and measurements of skinning and mechanical injury were made as follows:

Skinning: Ten-pound samples of uniform-sized, unskinned tubers were placed in a small barrel mounted horizontally on a wooden frame by means of a metal shaft. With a crank on the shaft, the barrel was turned through 10 revolutions at a slow, constant speed. Then the tubers were removed from the barrel and classified according to the percentage of the surface of the tubers which was feathered. Black and white charts were used as standards.

Mechanical Injury: A second standard-size barrel was fitted with a metal shaft through points midway between the two ends and mounted on the wooden frame. Ten-pound samples of uniform-sized, unbruised tubers were placed in the barrel, which was turned end-over-end at a slow speed through 10 revolutions. Tubers were then removed, placed in bags and stored for a month at 50°F. Estimates of minor and major injuries, according to U. S. grade standards, were made by an inspector of the Maine Department of Agriculture.

Yield of Tubers

Unpublished results obtained by the writers in Aroostook County, Maine, indicate that under the climatic conditions prevailing, potato tubers begin to form in early July. Under conditions of moderate fertilizer application and good growing conditions, rate of yield increase of tubers mounts gradually through July and then maintains a rather steady rate through most of August. Then the rate of yield increase gradually tapers off until the vines are killed by frost or other means. The increase in yield throughout the season may therefore be shown as a typical growth curve. Hawkins (5) showed that the peak rate of tuber development in the Green Mountain variety in 1939 occurred in early August, or 82-91 days following planting. Rate of tuber growth fell off following this period because of drought and early blight.

In 1945 (8) the average yields of four varieties of potatoes showed a daily increase from August 6 to 20 of approximately 9 bushels to the acre per day. In a 1950 experiment in which the yield of the Katahdin variety was 567 bushels on September 12, the rate of yield increase fell from 11 bushels per day in late August to 5 bushels in early September. With better insect and disease control and heavier fertilization in recent years, tubers continue to increase in yield at higher rates later in the season than was true 5 or more years ago. It is obvious, of course, that the rate of increase in yield of tubers per acre will vary for different seasons and within the same season, depending upon weather conditions, rate of fertilization, disease and insect control, and final yield level attained.

In the 1951 experiment the average increase in yield for the four potato varieties from green vines between August 14 and 24 was 8.4 bushels to the acre per day. Between August 24 and September 3 the average increase was 9.6 bushels and between September 3 and 23, 4.1

bushels. Yields for the three methods and dates of kill are shown in table 1. Average increases in yield for the four varieties and three methods of kill were 9.4 bushels between August 14 and 24 and 6.7 bushels between August 24 and September 3. Highly significant increases in yield for each 10-day period were found for all varieties.

Significant differences in yield were also found between methods of kill of 3 of the 4 varieties. Average yields for cutting, dinitro spray, and arsenical spray methods of kill were 481, 503 and 510 bushels per acre, respectively. In addition, yields increased on the average by 10 bushels from the first harvest 10 days after each date of kill to the second harvest 10 days later. This indicates an appreciable translocation to, and growth of, tubers after the vines appear practically dead. In this regard, Follstad (3) reported a yield increase of 57 bushels after potato vines were killed by frost.

It may be concluded from these results that yield continues to increase as long as portions of the vines are succulent. Therefore, if time until harvest and larger sized tubers are not important, slower methods of kill have the advantage of resulting in higher yields, as compared with the immediate destruction of the vines by cutting or rotobeating.

Specific Gravity of Tubers

Specific gravity of Katahdin tubers harvested at weekly intervals at Presque Isle, Maine, in 1950 increased gradually from 1.038 on July 15 to 1.073 on August 24 and August 30. Tubers harvested September 7 showed a lower value of 1.070. By September 12 specific gravity had increased again slightly. Smith and Nash (6) reported that potatoes grown in western New York increased in specific gravity from August 16 to September 7, but then decreased slightly to the last harvest on October 5. Early planting resulted in highest specific gravity at the first date of harvest, but made little difference at the last two harvest dates.

In the 1951 experiment, as shown by data in table 2, specific gravity increased from an average of 1.067 for four varieties killed on August 14 to 1.071 on August 24 and 1.077 on September 3. Tubers from green vines had also increased an average of 0.004 more by September 23. Most increases for individual varieties during the two earlier periods were statistically significant. There were also significant differences in specific gravity of tubers of all varieties from vines killed by different methods. Averages for cutting, dinitro spray, and arsenical spray were 1.070, 1.072, and 1.072, respectively. As was the case with yield, specific gravity of tubers grown in this experiment tended to increase as long as the vines remained alive. There was no difference in specific gravity on the average, however, for tubers harvested 10 and 20 days after each date of kill.

Length of period and conditions of growth are the probable factors causing a difference between seasons as to the time at which the tubers reach their maximum specific gravity, or total solids content. For example, in 1950 a warm, dry period occurred in May, which caused the potato plants to emerge quickly and initiate early growth. During this season specific gravity reached its maximum in mid-August. In contrast, the 1951 season was characterized by a late, cool spring and continuing

TABLE 1.—*Effect of date and method of kill on yield of potatoes.*

Variety and Method of Kill[1]	Date of Kill[2] and Yield—Bushels per Acre				
	August 14	August 24	September 3[3]	Ave., All Dates	L.S.D., 5 per cent level
Chippewa:					
Cutting	461	565	608	545	—
Dinitro spray	501	606	656	588	—
Arsenical spray	484	573	601	553	—
L.S.D., 5 per cent level	—	—	—	21	—
Kennebec:					
Cutting	417	526	576	506	—
Dinitro spray	407	531	577	505	—
Arsenical spray	467	565	584	539	—
L.S.D., 5 per cent level	—	—	—	N.S.	—
Katahdin:					
Cutting	353	415	518	429	—
Dinitro spray	358	419	531	436	—
Arsenical spray	394	442	548	461	—
L.S.D., 5 per cent level	—	—	—	26	—
Green Mountain:					
Cutting	337	455	543	445	—
Dinitro spray	387	484	576	482	—
Arsenical spray	386	499	573	486	—
L.S.D., 5 per cent level	—	—	—	19	—
Ave. 3 methods of kill:					
Chippewa	482	581	622	562	18
Kennebec	430	541	579	517	33
Katahdin	368	425	532	442	44
Green Mountain	370	479	564	471	49
Ave., all varieties	413	507	574	498	—

[1]Dinitro spray — 3 pints Sinox General plus 4 gallons fuel oil per 100 gallons applied per acre; arsenical spray — 2 gallons vine killer (40 per cent As_2O_3) 100 gallons per acre.

[2]Potatoes were planted on May 26. Dates of kill thus represent periods of 80, 90, and 100 days after planting.

[3]At this date 10-15 per cent of the leaves of Chippewa and Kennebec were yellowing and maturing naturally. Katahdin and Green Mountain vines were still green.

cool, rainy weather during much of the summer. As a result, maximum specific gravity of the tubers was not reached until late in September.

In the 1951 experiment, specific gravity of the Green Mountain variety was highest, followed by Kennebec, Katahdin, and Chippewa. Mealiness of these varieties grown in Maine is usually in the same order — Green Mountain and Kennebec being mealy, Katahdin mealy to slightly waxy, and Chippewa quite waxy.

TABLE 2.—*Effect of date and method of kill on specific gravity of tubers.*

Variety and Method of Kill	Date of Kill and Specific Gravity of Tubers				
	August 14	August 24	September 3	Ave., All Dates	L.S.D., 5 per cent level
Chippewa:					
Cutting	1.059	1.063	1.068	1.063	——
Dinitro spray	1.060	1.064	1.067	1.064	——
Arsenical spray	1.063	1.064	1.069	1.065	——
L.S.D., 5 per cent level	——	——	——	0.001	——
Kennebec:					
Cutting	1.067	1.073	1.082	1.074	——
Dinitro spray	1.069	1.072	1.080	1.074	——
Arsenical spray	1.072	1.074	1.083	1.076	——
L.S.D., 5 per cent level	——	——	——	0.001	——
Katahdin:					
Cutting	1.062	1.070	1.076	1.069	——
Dinitro spray	1.065	1.071	1.077	1.071	——
Arsenical spray	1.064	1.069	1.076	1.070	——
L.S.D., 5 per cent level	——	——	——	0.001	——
Green Mountain:					
Cutting	1.067	1.073	1.080	1.073	——
Dinitro spray	1.080	1.077	1.082	1.080	——
Arsenical spray	1.075	1.075	1.082	1.077	——
L.S.D., 5 per cent level	——	——	——	0.001	——
Ave. 3 methods of kill:					
Chippewa	1.061	1.064	1.068	1.064	0.003
Kennebec	1.069	1.073	1.082	1.075	0.003
Katahdin	1.064	1.070	1.076	1.070	0.005
Green Mountain	1.074	1.075	1.081	1.077	0.004
Ave. all varieties	1.067	1.071	1.077	1.072	——

SKINNING OF TUBERS

Shallow skinning, or breaking of the periderm, of potato tubers does not seriously lower their value for eating. The skinned areas soon turn dark, however, giving an undesirable appearance, especially when the potatoes are washed. Skinning is thus undesirable from the standpoint of marketing an attractive pack of potatoes.

The skinning index values for four varieties, as affected by date and method of kill and time of harvest, are given in table 3. Fairly consistent index values, indicating the percentage of the surface of the tubers affected, were obtained.

The most marked and consistent difference in skinning of all varieties was found between the 10 and 20-day times of harvest after the August 14 and 24 dates of kill, and for Green Mountain and Katahdin after the kill on September 3. At this last date there was no difference in skinning between the 10 and 20-day intervals with the Chippewa and Kennebec

TABLE 3.—*Effect of method and date of kill and date of harvest on skinning of four varieties of potatoes.*

Variety and Method of Kill	Skinning Index[1] of Tubers for Various Dates of Kill and Harvest: August 14, 10 Days Later	August 14, 20 Days Later	August 24, 10 Days Later	August 24, 20 Days Later	September 3, 10 Days Later	September 3, 20 Days Later
Chippewa:						
Cutting	41	39	43	33	28	33
Dinitro spray	41	37	36	29	32	35
Arsenical spray	49	37	46	25	36	32
Green vines—not killed	50	47	—	—	—	35
Ave., 3 methods of kill	44	38	42	29	32	33
Kennebec:						
Cutting	55	50	59	29	35	37
Dinitro spray	50	50	51	38	39	43
Arsenical spray	58	55	55	33	39	41
Green vines—not killed	58	44	—	—	—	41
Ave., 3 methods of kill	54	52	55	33	38	40
Katahdin:						
Cutting	52	33	34	27	36	33
Dinitro spray	55	32	46	29	42	38
Arsenical spray	55	43	40	37	39	32
Green vines—not killed	57	50	—	—	—	32
Ave., 3 methods of kill	54	36	40	31	39	34
Green Mountain:						
Cutting	42	38	45	32	45	33
Dinitro spray	42	32	50	38	43	31
Arsenical spray	44	34	53	37	48	41
Green vines—not killed	43	53	—	—	—	38
Ave., 3 methods of kill	43	35	49	36	45	35

[1]Skinning index is a weighed average of the percentage of the surface of 10-pound samples of tubers which are feathered. Values are averages for 2 replications.

varieties, which were maturing normally at this time. The effect of the normal process of maturing on reduction in skinning is obvious from the average values for the four varieties harvested from green vines. The index values were 52, 48, and 37 per cent, respectively, for August 24 and September 3 and 23. There was no appreciable difference between skinning of the two earlier and two later varieties harvested on these dates.

There were also significant reductions in skinning of all varieties harvested from vines killed by the 3 different methods at progressively later dates. These results substantiate the general observation that skinning of tubers late in the harvest season, even from green vines, is less than it is earlier in the season under otherwise similar conditions of handling.

From the decrease in skinning found for the longer time interval between date of kill and of harvest, it might also be expected that the most rapid rate of kill would result in the least skinning. As an average for the four varieties, this was found to be true. Average skinning values for cutting, dinitro spray, and arsenical spray were 38, 40, and 42 per cent, respectively. Only in the Katahdin variety, however, was skinning significantly lower for cutting than for the chemical sprays. Of the four varieties, Kennebec skinned the most, 45 per cent, and Katahdin the least,

39 per cent. These values appear to be in agreement with the experience of growers handling these varieties.

Mechanical Injury to Tubers

Mechanical injury, or bruising, of potato tubers is classified in U. S. grade standards according to the percentage of the tuber which is discolored or otherwise affected. Injuries are commonly designated as minor when 5 per cent or less of the weight of the tuber is affected and major, or damage, when more than 5 per cent is affected.

A method of measuring injuries similar to the one used in the present study — that of tumbling the tubers from one end of a container to the other — apparently has not been reported previously. Werner and Dutt (9) and others have generally used the method of dropping tubers a certain height on to a hard surface and measuring the percentage of bruises or cracking which results.

Data on the effect of date of kill and harvest and of temperature on injuries to four potato varieties are given in table 4. If one considers only the effect of date and method of kill, there is little relation of these factors to injury, except that the most major and total (minor plus major) injuries occurred on September 23 and the least total injury on August 24. In general the method used resulted in excessive amounts of injury, more than is normally encountered in the various stages of potato handling. This indicates that severity of the test should perhaps be reduced somewhat in any further use of this method.

Table 4.—*Effect of variety, date of kill and harvest, and temperature on mechanical injury to potato tubers.*

Variety and Injury	Injury to Tubers for Various Dates of Kill and Harvest — Per cent[1]						
	August 14		August 24		September 3		
	10 Days Later	20 Days Later	10 Days Later	20 Days Later	10 Days Later	20 Days Later	Ave.
Major Injuries:							
Chippewa	2	15	21	1	3	50	15
Kennebec	2	17	18	1	5	25	11
Katahdin	0	0	0	2	1	28	5
Green Mountain	16	23	27	10	10	59	24
Ave., all varieties	5	14	17	4	5	41	—
Major and Minor Injuries:							
Chippewa	64	77	88	80	77	100	81
Kennebec	70	78	76	79	70	92	77
Katahdin	51	64	71	77	82	97	73
Green Mountain	64	79	82	83	84	98	83
Ave., all varieties	62	75	79	80	78	97	—
Mean Temperature at Time of Harvest —Degrees F.:	62	53	53	68	68	53	—

[1]Values are averages for duplicate samples from vines killed by three different methods.

In contrast to the inconclusive results of the effect of date of kill and harvest on mechanical injury, temperature at time of harvest and testing of the samples had a pronounced effect. With all three dates of kill a lower mean air temperature at time of harvest resulted in marked increases in the average amount of major injuries and a somewhat less pronounced increase in total injuries. In regard to temperature, it is a common observation among growers and handlers of potatoes that tubers from a cold bin crack much more severely when handled than if the potatoes are warmed before handling. Edgar (2) found that warming bins of potatoes at 36° to 50° before grading reduced thumbnail cracks markedly.

Wright (10) found in tests simulating shipment of carload lots of potatoes that 65 per cent of the tubers were injured when stored and tested at 32° F., as compared with 31 per cent stored and tested at 50°. Similar results were obtained with potatoes stored at 50°, but subjected to temperatures of 32° and 50° during the tests. This indicates that both temperature of storage and temperature of testing influence mechanical injury. Similarly in the 1951 data in table 4, both soil temperatures prior to harvest and temperatures at the time of the tests undoubtedly influenced injury. The effect of temperature on injury is undoubtedly more important under conditions of rough handling than under conditions of careful digging and handling.

The explanation of more injury at lower temperatures may be the increasing conversion of starch to sugar in the tubers with decreasing temperatures, as suggested by Werner and Dutt (9). More sugar in solution in the plant cells increases the turgor pressure and thus increases the tendency of the cells and tubers to burst apart if outside pressure is applied, such as occurs when the tuber strikes against a hard object.

Tubers of the Triumph variety in Nebraska (9) and the Green Mountain variety in Maine (1) have been found to be very susceptible to cracking under certain rainy conditions at time of harvest. Both of these varieties have been found to develop considerably higher contents of sugar under normal cool temperatures during harvest or cold storage temperatures than most other varieties. The development of sugar at low temperatures, however, does not fully explain the differences in injuries to all varieties. Other factors are undoubtedly involved.

The largest amount of major and total injury in 1951, as shown in table 4, occurred in Green Mountains. Bruising decreased in Chippewa, Kennebec, and Katahdin, respectively, the order of susceptibility to bruising and other injuries as generally reported by growers. Hardenburg (4) also reported more bruising in Green Mountain than in Chippewa or Katahdin potatoes in the markets of Cleveland, Ohio and Rochester, New York.

Loss in Weight and Value for French Fries after Storage

Specific gravity and loss in weight of the tubers from the 1951 experiment were determined in December and March, after approximately 3 and 6 months' storage at 40° F. Losses in weight, as percentages of the weight of tubers placed in storage, are given in table 5. Shrinkage of tubers harvested August 14 was highest and that of tubers harvested September 23 lowest. Shrinkage was intermediate for August 24 and

TABLE 5.—*Percentage loss in weight of tubers harvested at different dates and stored at 40°F. and 75-80 per cent relative humidity.*

Date of Harvest	Percentage of Initial Storage Weight Lost[1] Aug.-Sept. to Dec.	Dec. to Mar.	Total
Aug. 14	3.4	2.3	5.7
Aug. 24	2.5	1.6	4.1
Sept. 5	2.2	1.4	3.6
Sept. 15	2.4	1.5	3.9
Sept. 25	2.0	1.4	3.4

[1]Determined by weighing 20-tuber samples, on which specific gravity determinations were also made.

September 3 and 13 dates of harvest. As has usually been reported, the various lots of tubers lost more weight during the September to December period than from December to March. There were no consistent differences in shrinkage between varieties or methods of killing the vines. No sprouts were removed.

Specific gravity of the tubers increased slightly on the average over the storage period. This indicates that under the conditions of a temperature of 40°F. and relative humidity of 75 to 80 per cent, water was lost by evaporation at a more rapid rate than dry matter was lost through respiration. Similar results were obtained previously (7) at 36°, 40° and 50° under similar conditions of relative humidity.

Color and texture ratings for French fries made from the various lots of tubers in late March are given in table 6. Darker color, indicating

TABLE 6.—*Color and texture ratings of French fries made in late March from tubers harvested at different dates and stored at 40°F.*

Date of Harvest	Variety and Rating[1] Chippewa	Kennebec	Katahdin	Green Mt.	Ave.
Color Ratings:					
August 14	2.0	2.7	1.0	1.0	1.7
" 24	2.9	3.8	2.5	1.4	2.7
September 5	2.6	3.5	1.8	1.3	2.1
" 15	2.5	3.8	2.4	1.5	2.6
" 25	3.0	4.1	2.9	2.3	3.1
Ave.	2.6	3.6	2.1	1.5	—
Texture Ratings:					
August 14	1.8	2.4	2.3	2.9	2.4
" 24	1.7	2.8	1.8	2.9	2.3
September 5	1.6	2.3	1.8	2.7	2.1
" 15	1.4	1.9	1.3	1.7	1.6
" 25	1.2	2.0	1.5	1.7	1.6
Ave.	1.5	2.3	1.7	2.4	—

[1]Cores from 10 tubers per sample were individually rated as follows for color: 1—very dark; 2—dark; 3—medium dark; 4—medium; 5—medium light; 6—light; and 7—very light. No tubers stored at 40° rated lighter in color than 5. Texture ratings were made as follows: 1—watery, or "soggy"; 2—intermediate; and 3—mealy.

more development of sugars, was found for the August 14 date of harvest than for later dates. The lightest color, indicating no appreciable sugar development, was found for the most mature tubers harvested September 23. The Kennebec variety developed least sugar in storage, followed in order by Chippewa, Katahdin and Green Mountain.

Texture ratings and mealiness of the French fries were highest for the tubers harvested on August 14 and decreased with later dates of harvest. French fries of the Green Mountain variety were most mealy, followed by Kennebec, Katahdin and Chippewa. Except for the results obtained among the various varieties, which are those usually obtained for French fries or potato chips of these varieties, the writers can offer no valid explanation of the texture or color ratings, as affected by date of harvest in 1951. No differences were found in the ratings of Katahdin tubers harvested in 1950 over the period of August 22 to September 19 and stored under similar conditions as in 1951.

Summary

Field plot experiments were conducted in 1950 and 1951 to study the effect of date and method of killing the vines on yield and various characters affecting the quality of the tubers.

Yields of tubers increased as long as any portions of the vines remained alive. Because of this, slower methods of kill resulted in higher yields than more rapid methods of kill.

Specific gravity of tubers grown during the warmer season of 1950 reached a maximum in mid-August. The specific gravity of tubers grown during the cooler, more rainy 1951 season, however, increased as long as the vines remained alive. In this year, as was true of yield, slower methods of kill resulted in higher specific gravity of the tubers.

Susceptibility of the tubers to skinning decreased as the vines matured. Early in the harvest season skinning was markedly reduced by harvesting 20 days, rather than 10 days, following the date of killing the vines.

Susceptibility of the tubers to mechanical injury increased markedly with lower temperature during harvesting and testing. The tubers also injured somewhat more easily with advance in maturity.

Shrinkage, or loss in weight, during storage was lower for more mature tubers than for those harvested earlier in the season. Lightness of color of French fries made from the tubers increased with maturity. Mealiness of French fries, however, decreased as the tubers matured prior to harvest.

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A RAPID METHOD OF TESTING PLANTS IN THE FIELD FOR POTATO VIRUS X[1]

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Seedlings grown at Alma, New Brunswick, as part of the National Potato Breeding Project of the Department of Agriculture, are compared in growth, quality, yields, and other factors with an established variety. In the past, the variety Green Mountain planted in alternate rows with the seedlings has been used. However, all stocks of Green Mountain carry potato virus X, and the spread of this virus to the seedlings is undesirable. (Potato virus X can spread from plant to plant merely by leaf contact.) Often infected plants develop a mild mosaic or other symptoms and can be discarded at once, but sometimes symptoms are faint or masked and infected plants pass unnoticed to serve as additional sources of infection. When a seedling is propagated for release, a large portion of the resulting tubers may carry a mild strain of virus X, which under normal conditions causes faint or no visible symptoms. Certain weather conditions such as cool dull days, however, may cause these plants to exhibit a mild mosaic, which confuses inspectors. Also even mild strains of virus X will reduce yields (1, 2, 3, 4). The method herein described has been used at Alma to test seedlings in the field for mild mosaic, and would be useful in a study of the field spread of potato virus X.

Method

In contrast with inoculations of indicator plants, serological tests are less expensive and give results in a matter of minutes. An antiserum for potato virus X can be prepared from rabbits or other suitable animals. Infected tomato or tobacco plants should be used as the source of the virus, for the virus content of these is likely to be higher than that

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of potato (2). Four intravenous injections of purified virus or six intraperitoneal injections or clarified sap, given at weekly intervals, usually produce an antiserum with a titer greater than 1:1000. The method of testing is similar to the agglutination test described by van Slogteren (5), and consists of mixing drops of crude sap with antiserum on glass slides.

The materials required (Figure 1) consist of a rubber band (about an inch wide) tacked over the squared end of a stake from 1 to 2 feet long. A clothespin inserted under the rubber band holds a glass slide horizontally after the pointed end of the stake has been inserted into the ground beside the plant to be tested. Two or three leaflets are pulled from the plant to be tested and a suitable tool[3] is used to express two drops of sap on the glass slide.

A drop of diluted antiserum is then added to one drop of sap and a drop of diluted normal serum or physiological salt solution is added to the other. First the sap and the normal serum, and secondly the drop of sap and antiserum are stirred with a glass rod. A few minutes after stirring, agglutination in the drop to which antiserum has been added and no agglutination in the other indicates the presence of potato virus X. Agglutination in the mixture of sap and normal serum is an unspecific reaction and the test should be repeated. Light reflected from the sky by holding a mirror below the slide facilitates determining agglutination.

If consecutive plants are to be tested in a row, four people working as a team can test more than 125 plants an hour. About ten stakes with clothespins are required. One person sets the stakes with clean glass slides beside the plants to be tested and rotates the used stakes to untested plants. A second expresses two drops of sap from the plants to be tested on each glass slide; a third adds the antiserum and the normal serum and mixes the resulting drops; and a fourth reads the results, marks infected plants, and removes the used slides when the test is complete.

Certain precautionary measures are advisable. (First), The dilution of the antiserum used should be determined by experiment, since agglutination may be inhibited if the virus is present in great excess. An antiserum having a titer over 1:500 has given good results when used at 1:25; high concentrations of antiserum reduce the chances of inhibition. (Second), Potato virus X can be carried on the hands, so that when pulling leaflets from a plant care should be taken to touch only the leaflet to be used. (Third), Virus on the extracting tool or stirring rod may contaminate the expressed sap and give positive tests with sap from healthy plants. This can be avoided by rinsing both tools in soapy water and drying them on a towel after each test. Finally, in removing infected plants, care should be taken that their leaves do not contact those of uninfected plants.

Summary

A method is described whereby a team of four people can use a variant of the serological precipitin reaction to test over 125 plants an hour in the field for the presence of potato virus X.

[3]Bernard fence pliers manufactured by W. Schollhorn Co., New Haven, Connecticut (Patent no. 1064956) were used.

Figure 1.—Materials used to test plants in the field for potato virus X. From left to right: stake with clothespin holding glass slide, glass stirring rod, tool for extracting sap, bottles of diluted antiserum and normal serum, and box of glass slides.

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THE INFLUENCE OF IRRIGATION ON THE YIELD AND QUALITY OF POTATOES ON LONG ISLAND[1]

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Irrigation has only become a major factor in the production of potatoes on Long Island during the past few years. Although it was shown, during the dry seasons of 1939 and 1944, that irrigation was necessary for crop insurance, only recently has the general use of irrigation been considered essential for good commercial growing of potatoes. Work has been conducted at the Long Island Vegetable Research Farm since 1939 for the purpose of studying the influence of irrigation on the response of potatoes to other cultural practices.

Recently, interest has been centered on the problem of determining more accurately the optimum frequency and amount of irrigation during varying seasons. This paper is a short report of one such series of experiments over a three-year period.

MATERIAL AND METHODS

In 1949 the plots were nine rows wide and 54 feet long. The center 336 feet of the middle 3 rows was used for harvest records. All water was applied with an overhead small pipe system, blank nozzles being used to vary the applications in different plots. Watering was done only when no wind was blowing. These tests included four treatments arranged in a 4 x 4 Latin Square.

All watering was done on the basis of soil moisture as determined by a tensiometer. The treatments were designated by the maximum tension permitted before water was applied. These were 5, 10 and 20 inches of mercury plus a treatment receiving no irrigation. In all cases a calculated amount of water was applied to bring the top 12 inches of soil in the plot up to field capacity, about 25 per cent in this case. Each plot was watered individually on the basis of a tensiometer set in the center of the middle row.

Katahdin potatoes were planted on May 2, 12 inches apart in 34-inch rows with 2500 pounds per acre of 5-10-5 fertilizer in bands. The normal practices were followed for spraying and cultivation and irrigation treatments were started on June 17.

In 1950 the plots were 10 rows wide and 30 feet long, the center 25 feet of the middle 6 rows being used for records. There was a 2 foot aisle between plots to break the rows since water was applied in the furrows by flooding. The 4 rows between plots were discarded because of sprayer wheel rows and border effects. The treatments were 2.5, 5, 10, 20 and 40 inches of mercury tension plus no irrigation. Water was

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metered on each row by a fire hose and again the quantity applied was sufficient to bring the top 12 inches of soil up to field capacity. Each plot was watered individually. There were 9 replications of the treatments arranged in randomized block design. The 40-inch treatment was measured with moisture blocks since the tensiometers were useless above 25 inches.

Green Mountain potatoes were planted on May 3 and standard practices carried out. The irrigation treatments began on June 13.

In 1951 the plots were 10 rows wide and 34 feet long with 5 foot aisles breaking the rows between plots. The center 25 feet of the middle 6 rows was used for yield records. The experiment was the same as in 1950 except that the 2.5-inch treatment was dropped. There were 9 replications again. Green Mountain potatoes were planted on April 24 with 2000 pounds per acre of a 7-7-7 fertilizer in bands. These treatments were started on June 8.

During seasons the tests were conducted in all years the crop was irrigated until maturity or approximately 10 weeks each year. The vines were killed in 1950 and 1951 but this process was not necessary in 1949. In 1949 and 1950 the specific gravity was determined in all samples after being stored for a period of 4 months and in 1951 it was determined the day after harvest.

Results

In table 1 are given the yields of U. S. No. 1 potatoes from the irrigation treatments in the three years of the experiment. Figure 1 is a graphic presentation of these data. Here it is seen that in 1949, a very dry season, the only significant effect was between no irrigation and some irrigation. In 1950 the major difference was between no irrigation and the 40 inches of tension. The maintenance of soil moisture at higher levels reduced the yield consistently, there being a significant difference between the extremes. In 1951 the yields increased with additional water until the tension was reduced to 20 inches and there was no reduction with more water, neither was there any benefit obtained from additional water.

TABLE 1.—*Yields of potatoes as influenced by soil moisture content.*

Yield of Potatoes
U. S. No. 1 Bus. per Acre

Maximum Tension Inches of Mercury	1949	1950	1951
2.5	......	528	......
5	443	546	477
10	459	552	465
20	419	554	499
40	......	574	442
No Irrigation	258	537	367
L.S.D. @ $P \leq .01$	60	33	43

The specific gravity data are given in table 2. In 1949 irrigation increased the specific gravity over no irrigation and there were no differences between the levels of irrigation. In 1950 a similar situation existed although two of the drier treatments gave specific gravities not significantly different from no irrigation. In 1951 there was a significant reduction in specific gravity by the 40-inch treatment compared with no irrigation and none of the other treatments was different from the no irrigation treatment.

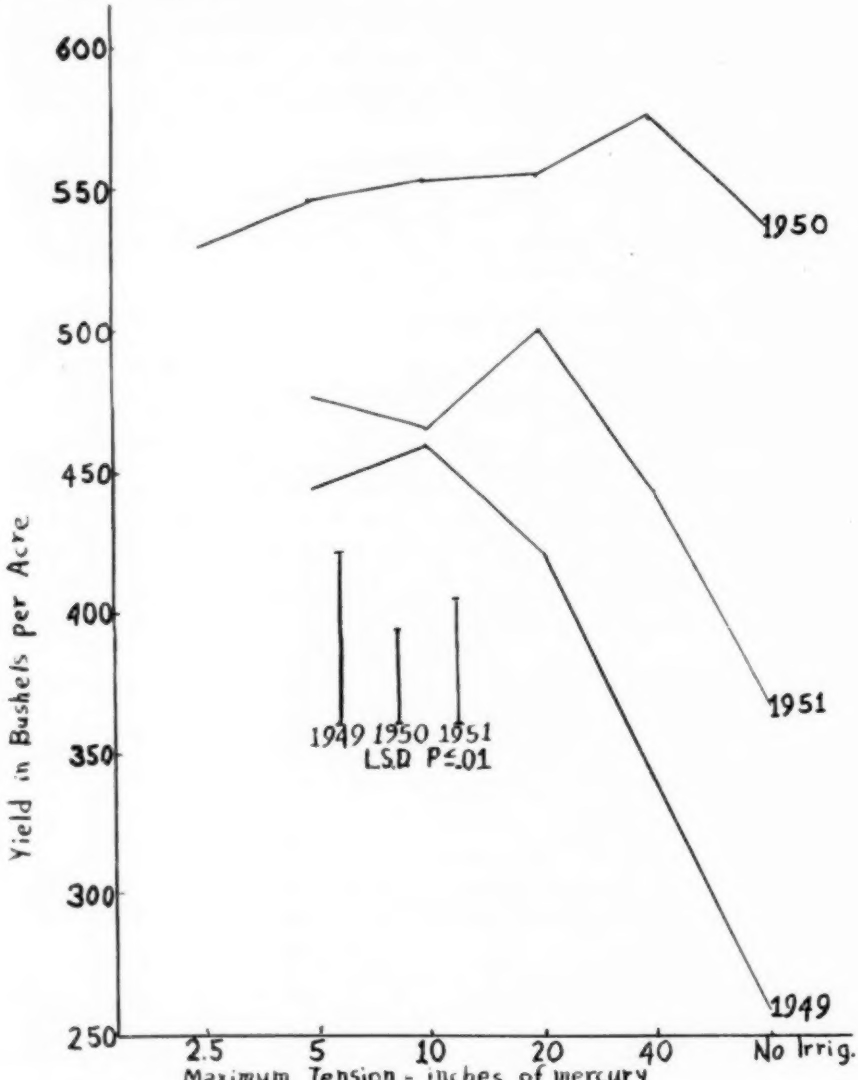

Fig. 1. Yield of potatoes as influenced by soil moisture content.

TABLE 2.—*Specific gravity of potatoes as influenced by soil moisture content.*

Maximum Tension Inches of Mercury	Specific Gravity of Potatoes		
	1949	1950	1951
2.5	....	1.093	....
5	1.063	1.095	1.083
10	1.063	1.093	1.084
20	1.061	1.092	1.082
40	....	1.092	1.080
No Irrigation	1.055	1.089	1.083
L.S.D. @ $P \leq .01$	.003	.004	.003

Table 3 is a record of the water applied and also the rainfall for the season. This is given to show how the treatments were consistent in 1950 and 1951 but much different in 1949. This difference was probably caused by the fact that locating the tensiometer in the row with flood irrigation required higher applications of water to get the same response from the tensiometer than would be obtained by overhead irrigation. The 40-inch treatment corresponded closest to the commercial application of 1.5 inches every 10 days.

SUMMARY AND DISCUSSION

There are two major points to be gathered from these experiments. It is easy to over-irrigate, even in a dry year and the result is either a reduction in yield, as was obtained in 1950, or a failure to get enough increase in yield to pay for the cost involved as was obtained in 1949 and 1951. The exact optimum level of minimum soil moisture may vary from year to year but it seems to be in the neighborhood of 20 to 40 inches of mercury tension. This was a level of 12 per cent to 15 per cent moisture in the soil or about 50 per cent to 60 per cent of field capacity. Applications of 1.2 to 2.2 inches of water applied frequently enough to prevent excessive drying of the soil seemed to be adequate for potatoes on Long Island. Smaller and more frequent applications were not so good. For a grower with a large acreage to be covered by a portable pipe system, judgment and luck have to be combined to begin the irrigation soon enough so that the first fields covered are not over-watered and the last ones do not suffer from drought.

An additional item of interest is that the irrigation that gives good increases in yield of potatoes very seldom reduces the specific gravity and is more likely to increase it. It often happens that increasing yields of potatoes results in poorer quality but such is not the case with irrigation.

TABLE 3.—*Record of water supplied to potato crops during 18 weeks growing season.*

Max. Ten. of Mer.	Ave. Water Supply per Wk. Acre — Inches			Total Water Available Acre — Inches			Water Added Acre — Inches			No. Irrigations (10 Weeks)			Ave. Amt. per Irrigation		
	1949	1950	1951	1949	1950	1951	1949	1950	1951	1949	1950	1951	1949	1950	1951
2.5	......	1.44	......	......	25.9	......	......	11.3	......	....	26	....	......	.44	......
5.0	1.16	1.34	1.35	20.9	24.1	24.3	10.9	9.5	11.3	10	14	17	1.09	.68	.67
10.0	1.04	1.29	1.28	18.7	23.3	23.1	8.7	8.7	10.1	7	11	9	1.24	.80	1.12
20.0	0.88	1.21	1.11	15.9	21.8	20.0	5.9	7.2	7.0	4	6	4	1.48	1.20	1.75
40.0	......	1.19	1.03	......	21.4	18.6	......	6.8	5.6	....	3	3	......	2.27	1.87
No Irrigation	0.56	0.81	0.72	10.0	14.6	13.0	0	0	0	0	0	0	0	0	0